Mainz "measurement" of the $E2/M1$ ratio in the $N-\Delta$ transition

Beck *et al.* [1] have recently reported precise measurements of differential cross sections and polarized photon asymmetries on the reaction $\vec{\gamma} p \to p\pi^0$, using tagged photons in the energy region 270 to 420 MeV, thus spanning the $\Delta(1232)$ resonance. This augments the data from the Brookhaven LEGS facility [2].

Let us emphasize from the outset that the $E2/M1$ ratio in the $N-\Delta$ transition *is not directly measured* by Beck *et al.*, despite the title of their paper. This is an *inferred* quantity requiring theoretical modelling of the data. Here, we take issue with some points of the analysis reported by Beck *et al.* We show that our $E2/M1$ ratio, R_{EM}, extracted from the data of Beck *et al.* [1] is *substantially* different from what is obtained in Ref. [1]: while Beck *et al.* obtain this ratio to be -(2.5±0.2±0.2)%, we get -(3.19±0.24)%. This difference is mostly due to the inaccuracy introduced by the use of approximations in identifying R=$C_\parallel/(12A_\parallel)$ with R_{EM}, in Eqs. (7,8) of Ref. [1]. We also emphasize that the systematic error of ± 0.2% for R_{EM} estimated by Beck *et al.* due to "... limited angular efficiency for detecting the recoil proton ... and from ignoring the isospin 1/2 contributions", *does not* include the error made by them in ignoring the E_{1+} multipole in $A_\parallel$.

We start with the coefficients characterizing the differential cross section, assuming dominance of s- and p- waves:

$$A_\parallel = |E_{0+}|^2 + |3E_{1+} - M_{1+} + M_{1-}|^2 \ , \tag{1}$$

$$B_\parallel = 2\mathrm{Re}\left[E_{0+}(3E_{1+} + M_{1+} - M_{1-})^*\right] \ , \tag{2}$$

$$C_\parallel = 12\mathrm{Re}\left[E_{1+}(M_{1+} - M_{1-})^*\right] \ , \tag{3}$$

correcting an error in Eq. (4) of Ref. [1]. Key to the analysis of Beck *et al.* is identifying R with R_{EM}. This is imprecise for the following reasons. First, this requires neglecting M_{1-}, E_{0+} and the isospin 1/2 components of M_{1+} and E_{1+} in Eqs. (1-3), and in addition neglecting E_{1+} in Eq. (1) altogether. Second, equality of R and R_{EM} is not a good approximation even at the K-matrix pole as implicitly assumed in Ref. [1]. It gets far worse, away from this pole. Finally, contrary to the assertions of Ref. [1], Re$(M_{1+} - M_{1-})$ is *not* zero and ImM_{1+}, ImM_{1-} are *not* purely isospin 3/2, even at the K-matrix pole. These effects need to be estimated in a model, as done by us below. We realize that some of these approximations are unavoidable for Beck *et al.* in order to extract R_{EM} from the data, in absence of a model. The best they can do is not to neglect E_{1+} in Eq. (1), as we show below.

We use our effective Lagrangian approach [3] to analyze the Mainz data set without making any of the above approximations, and retaining partial waves beyond s and p. We get at the K-matrix pole, 338.4± 0.5 MeV, $M1$ = 282.5± 1.3, $E2$ = -9.00±0.66, both in units of $10^{-3}\mathrm{GeV}^{-1/2}$, and R_{EM} = -(3.19±0.24)%; at 340 MeV, we get R_{EM} = -(3.09±0.24)%. The value of R at 340 MeV is -(2.69±0.17)%, consistent with the result of Ref. [1]. The difference between R and R_{EM}, given here, is mainly due to the isospin 3/2 piece of the E_{1+} in Eq. (1), neglected by Beck *et al.* This can be verified by using *their* value of R and correcting for the isopsin 3/2 piece of the E_{1+} amplitude. This gives $R_{EM} \approx$ -(2.9±0.23)%, in agreement with our value.

A comparison between the LEGS [2] and the Mainz [1] published data indicates no significant discrepancy between R_{EM} inferred from the former data base [4] and the present Mainz result presented here.

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